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SEWER CONSTRUCTION COST INDEX. CONSTRUCTION COST TRENDS. MUNICIPAL SEWERS

Public Health Service
Washington, D. C.

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SEWER CONSTRUCTION COST INDEX

Construction Cost Trends
Municipal Sewers

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U.S. DEPARTMENT OF HEALTH, EDUCATION,
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Public Health Service
Division of Water Supply and Pollution Control
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FOREWORD

Construction costs have risen steadily since the mid-1930's. The rate of increase has varied among the different types of engineering construction.

Because of its responsibility for the administration of grants-in-aid for the construction of waste treatment works under the Federal Water Pollution Control Act, the Public Health Service has developed means for the evaluation of progress in this field of construction. Contract award data have proven useful for this purpose, but these need to be adjusted to a standard base to assure comparability during a period of rising costs. This can be done through use of appropriate construction cost indexes for treatment plants and sewers, the two principal categories of waste treatment works construction.

A sewage treatment plant construction cost index was developed by the Public Health Service in 1963 and documented in PHS Publication No. 1069. A companion cost index for sewer construction has just been completed and is presented in this report.

The Sewer Construction Cost Index was produced by Professor Raymond M. Jones of Howard University, on a personal services contract, under the supervision of Mr. Peter P. Rowan, Chief, Evaluation Section, Construction Grants Branch, Division of Water Supply and Pollution Control, Public Health Service. Computer programing was performed by Mr. William H. Mills, Jr., of the Basic Data Branch, Division of Water Supply and Pollution Control, Public Health Service.

DAVID H. HOWELLS, *Chief,*
Construction Grants Branch,
Division of Water Supply and
Pollution Control

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INTRODUCTION

During the period 1956–63 there was a marked increase in the amounts invested in the United States for minicipal sewage collection and disposal systems. Currently, over $600 million annually is being spent for the construction of municipal sewers; including collector, interceptor, outfall and pumping facilities, plus related appurtenances. Continued growth in sewer construction is anticipated over the next decade, in view of the backlog of needed sewer facilities and the increasing requirements associated with an expanding urban population. Estimates indicate that 588 million feet of sewer pipe will be needed by the year 1972 to meet these needs (*1*).

The growth in sewer construction is directly related to the Federal Water Pollution Control Act of 1956, as amended, which is administered by the Division of Water Supply and Pollution Control of the Public Health Service. One objective of this program is to encourage municipalities to undertake the construction of needed waste treatment works including interceptor and outfall sewers through the medium of incentive grants. A realistic assessment of the increased sewer construction activity and estimate of future construction needs require a sound appraisal of the changing purchasing power of the funds invested in this type of construction. A common denominator in the form of a valid construction cost index is indicated.

The several existing indexes were developed either for general broad fields of activity or for specific narrow uses. When applied to sewer construction they fail to reflect fully the changes and variations in costs over the years, due either to a weight or price bias, or both. Typical examples of weighted biases appearing in existing indexes are the exclusion of skilled labor, common labor, or basic construction materials. Price bias is demonstrated in other indexes by the use of a figure based on a single supplier, in a specific geographic location, rather than the general prices prevailing in that area or areas. Some of the existing indexes are those prepared by the American Appraisal Company (*2*), the Associated General Contractors (*3*), E. H. Boeckh & Associates (*4*), Marshall and Stevens (*5*), and *Engineering News-Record* (*6*).

As a first step in obtaining an accurate appraisal of costs in the sewerage field, the Sewage Treatment Plant Construction Cost Index (*7*) was developed. It soon became evident, however, that there were vast differences in quantities of material, men, and equipment required for sewer construction, as compared with plant construction, and that a second index designed specifically for sewer construction was necessary. This report develops and presents such an index.

BACKGROUND

Sewers are defined as the series of pipes and conduits including necessary appurtenances that collect and carry sewage from its point of origin (residences, business buildings, industrial institutions, etc.) to the point of final discharge, excluding building sewers and treatment facilities. This definition includes combined sewers, but excludes separate storm sewers.

The Sewer Construction Cost Index herein developed is designed to measure the rise and fall of costs for the specific commodity "sewer construction." It is the ratio of construction cost, at a specific time, to a base period construction cost.

The report *Sewage Treatment Plant Construction Cost Index* (7), discusses the relationship between price and cost index numbers and develops in detail the construction cost index. The construction cost index is defined as follows:

$$\text{Construction Cost Index} = \frac{(P_1Q_1+P_2Q_2+\cdots P_nQ_n)_a}{(P_1Q_1+P_2Q_2+\cdots P_nQ_n)_b}\times 100 = \frac{\sum P_aQ_a}{\sum P_bQ_b}\times 100 \quad (1)$$

$P_1, P_2, \cdots P_n$ are unit prices or wages of material and labor entering sewer construction, and $Q_1, Q_2, \cdots Q_n$ are the quantities of material and labor required in constructing the project; "a" and "b" are, respectively, a specific time of construction, and the base period time of construction.

This is a fixed base, weighted cost index, and is believed to be a substantially accurate indicator of the purchasing power of funds invested in sewer construction. Reasons for selecting a fixed base, weighted index are outlined in the *Sewage Treatment Plant Construction Cost Index* (7). The same factors apply to sewer construction.

Construction cost, as reported in the treatment plant index and as used in the sewer index, is equal to the sum of the following:

(1) Materials =concrete, lumber, iron, steel, etc., used in construction,
(2) Machines =process equipment and contractor's equipment used in construction,
(3) Men =skilled and common (heavy construction) labor employed during construction, and
(4) Money =overhead charged and profit earned during construction.

or

$$\text{Construction cost} = M_1+M_2+M_3+M_4$$

Consideration was given the possibility of using parts of various general or special purpose construction cost indexes, such as those

already mentioned (*2, 3, 4, 5, 6*) in the development of the sewer construction cost index. However, careful analysis of each brought out deficiencies, as pointed out, which proved to be too great to use for this purpose.

The construction described in this report is a statistically representative sewer installation project based on known quantities and costs, so that by using published price data available for the time period investigated, a responsive index reflecting the varying costs of sewer construction results.

This index, utilizing know quantities of labor and materials properly proportioned, has the advantage of being its own test for the base period. Because it has a fixed base, periodic surveys can be made to test whether or not the fixed base still reflects sewer construction practice. This method provides a yardstick to study the trends and magnitude of sewer project construction costs in constant dollar values. The two indexes—the Sewage Treatment Plant Construction Cost Index (PHS-STP) and the Sewer Construction Cost Index (PHS–S)— when used in conjunction, provide the tools necessary to equate sewerage projects, one to another, in both time and place.

ASSUMPTIONS AND BASE DATA FOR INDEX

The primary assumption is that this will be designed as a $1 million fixed base, weighted index, for a hypothetical sewer project. The amount of $1 million was selected arbitrarily for convenience.

Other assumptions are as follows:

1. The hourly output of labor remains constant, in spite of changing wage rates.
2. Quantities and kinds of material used in construction remain constant and available during the period under study.
3. Modern construction techniques are employed over the entire period.

In view of these assumptions, the index may be used for: (*a*) estimating construction costs at various times, (*b*) checking present costs with costs for similar projects of previous years, (*c*) verifying other cost data, and (*d*) forecasting future cost trends.

Weighting

This index is not designed to reflect right-of-way or land, engineering, legal, or fiscal costs; nor does it allow for errors, omissions and changes occurring after a contract award. It does include: (*a*) material cost, (*b*) contractor's plant cost (contractor's equipment and supplies used in construction but not incorporated in the finished

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project), (*c*) labor cost, and (*d*) overhead and profit cost associated with the project. These correspond respectively to the: (*a*) materials, (*b*) machinery, (*c*) men, and (*d*) money previously cited.

Base Period

The base period for this index is the 36-month period January 1, 1957 through December 31, 1959. This period conforms to the post-war base period for federal index numbers as defined by the Bureau of the Budget.

Statistical Characteristics of Hypothetical Sewer Construction Project

An analysis of the construction contracts and bid documents for sewer projects assisted under the Federal Water Pollution Control Act for the period 1956 through 1962, after elimination of all lump sum type bids, revealed:

(1) Total number of projects.....733
(2) Total contract dollar value.....$75,259,681
(3) Total length of pipe.....3,456,000 lin. ft.
(4) Range of pipe size.....8 to 96 in.

Of the projects analyzed, more than 80 percent were for communities of 25,000 population and less; whereas, on a dollar basis, more than 40 percent of the funds were expended by cities larger than 25,000 people. Geographically, these projects closely approximate the overall national distribution of projects and money in the sewer construction field. It is believed that this is a truly representative sample.

Further analysis disclosed that more than 90 percent of the projects included at least one bid item that was unique to the contract involved. Also more than 70 percent of the contracts had at least 65 bid items, excluding the pipe-in-place item. A multiplicity of items describing a single phase of construction calling for different materials, quantity units, and methods of installation also were observed. A typical example was the materials used in paving streets. These included chemicals, earth, crushed rock, sand and gravel, various classes of concrete, asphalt, etc. All such designated items have been grouped into a single construction category under "paving." Items such as lumber shoring, timber sheeting, steel sheeting, etc., whether left in place or removed, have been grouped into a single category, "sheeting and shoring." The eight categories found in table I represent the net result of such grouping of items or materials for a common purpose.

Table I.—Construction Categories and Costs for Sewer Construction, 1956-62*

Construction categories	Units	Total category cost	Average cost/unit	Percent of project cost
1. Paving	196,068 lin. ft.	$662,285.19	$3.377	.88
2. Sheeting and shoring	4,083 Mbf.	368,772.44	90.319	.49
3. Manholes	18,620 each	2,521,199.32	135.403	3.35
4. Earth excavation	826,190 cu. yds.	2,220,160.59	2.687	2.95
5. Rock excavation	175,356 cu. yds.	1,377,252.16	8.037	1.83
6. Seeding and sodding	23,545 sq. yds.	7,525.97	0.319	.01
7. Pipe in trench	3,456,162 lin. ft.	35,098,063.28	10.152	46.62
8. Lump sum items	L.S.	33,016,422.05	.....	43.87
Total sewer construction cost	.....	75,359,681.00	.....	100.00

* Analysis of projects assisted under the grants-in-aid program.

Table I presents the total number of units of material for each construction category, the total cost (contract) of each category, and the percent of total project costs represented by each category. For convenience, the average cost per unit was computed from the total costs and also is shown. Category 8 contains all the specially designed, unique, or one-of-a-kind type items such as inverted siphons, flow control devices, pumping stations less pumps, cutoff walls, etc. for which a lump sum price was given or could be assigned on the basis of all other prices being known.

The percent dollar distribution of these eight categories provided the basis for the hypothetical sewer construction project used in the development of the index. For convenience of data manipulation, a $1 million value was assigned to the hypothetical project. The percent of project cost when applied to the $1 million value produced the category costs for the hypothetical project. By using the average unit costs, the number of units for each construction category was obtained (table II).

DEVELOPMENT OF COST INDEX

Several steps are necessary to develop the cost index. First, the major construction categories must be determined. This was done and scaled down to a $1 million project, shown in table II. Next, it is necessary to determine unit costs assigned to the material, labor, contractor's plant, and overhead and profit for each construction category. These unit costs must then be reduced to quantities of selected materials, man-hours, and contractor's equipment rental hours.

Table 11.—Construction Category Cost for a $1 Million Hypothetical Sewer Construction Project

Construction categories	Percent of project cost	Total category cost	Average cost/unit	Units
1. Paving	.88	$8,800.00	$3.377	2,605.86 lin. ft.
2. Sheeting and shoring	.49	4,900.00	90.319	54.25 Mbf.
3. Manholes	3.35	33,500.00	135.403	247.41 each.
4. Earth excavation	2.95	29,500.00	2.687	10,979.78 cu. yds.
5. Rock excavation	1.93	18,300.00	8.037	2,276.97 cu. yds.
6. Seeding and sodding	.01	100.00	0.319	313.48 sq. yds.
7. Pipe in trench	40.62	406,200.00	10.132	43,921.98 lin. ft.
8. Lump sum items	43.87	438,700.00	.....	
Total sewer construction cost	100.00	1,000,000.00	.....	

This procedure is highly complex because of the wide range of types of material, trades, construction rates, field conditions, construction methods, and procedures. For example, more than 40 identifiable trades were involved in the construction of the projects used in this study. The relative lack of cost data for contractor's plant and overhead and profit further complicated the procedure. Subsequently this report clarifies the methods used to obtain these data.

After the quantities of material, labor, and equipment are established, they are combined with published price data for the selected areas of influence, to obtain individual project costs for each area. Base period project costs are obtained in the same manner and cost indexes may then be computed. Details of these procedures follow.

Determination of Category Component Costs

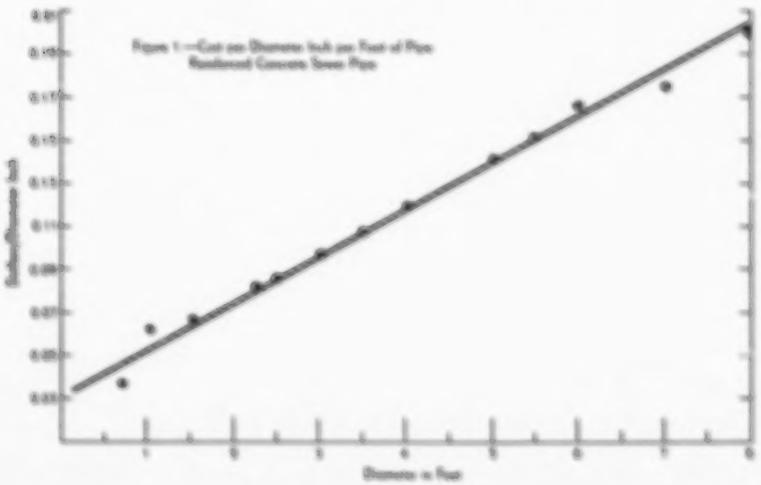
To determine unit costs for the four components—material, labor, contractor's plant, and overhead and profit—the same procedure used in the *Sewage Treatment Plant Construction Cost Index* (7) was followed. Costs for material and labor were found to be available generally. Historically, contractor's equipment prices or costs normally have not been published or available. The PHS–STP was developed on the basis of costs occurring in the Kansas City, Mo. area. To place the PHS–S in the same frame of reference, and because the data were available for the Kansas City area, the hypothetical sewer project was developed using this restricted price data.

Therefore, the model project category cost components were determined on the basis of prices prevailing in the Kansas City, Mo. area during August 1962. These values for the entire project are included as appendix A. This procedure provided cost information for mate-

rial, labor, and contractor's plant, and allowed the assignment of the balance of the total cost to overhead and profit.

To obtain the component costs for each category of construction for the model project, the units of material, labor hours, and contractor's plant rental time for each unit of construction had to be determined. Category 7 (Pipe in trench) is used to illustrate how these determinations were made. First, however, it is necessary to delineate special problems encountered in determining pipe costs.

Special Factors Concerning Pipe. The range in pipe materials and sizes presented a major obstacle to development of the index. Continuous price data on the many sizes of pipe included in the basic study do not exist for the time period on which the index is based. However, when each type of pipe material was examined on a cost per diameter inch per foot of length basis, a constant differential in price between sizes evolved. This is graphically illustrated in figure 1 for reinforced concrete pipe, and mathematically presented in appendix B. It was not necessary to use the procedure for cast iron pipe since it is priced on a pound basis.



To estimate the cost of pipe of a size for which no information is published, it is necessary to know the cost of one size of pipe of the same material. The unknown pipe cost is approximately equal to the known pipe cost expressed in cost per diameter-inch per foot plus the product of the difference in diameters and the slope of the curve (appendix B, part 2).

To further simplify index calculations, it was necessary to base pipe costs on equivalent pipe lengths. To arrive at such costs, the above

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procedure and the original pipe footage were used. Thus the pipe category calculations could be based on a single pipe price rather than a wide assortment of prices. To reduce the inherent bias caused by using the cost of a single size of pipe for this purpose, a composite pipe equal to the sum of the cost of both 12-in. and 24-in. pipe was used in the development of the index.

Distribution of costs for the various sewer pipe materials was based on the original projects studied under the grants-in-aid program. Lack of continuous price data on asbestos cement pipe for the historical period studied required an additional adjustment in the composite equivalent lengths of the other three materials evaluated to compensate for the exclusion of asbestos cement pipe in the index values. This adjustment was made on the basis of the costs of the other three materials and resulted in increases of 2.21 percent, 4.11 percent, and 41 percent respectively, for vitrified clay, concrete and cast iron.

Table III presents the original and adjusted cost distribution and equivalent lengths for the various types of sewer pipe within the size ranges studied.

Table III.—Cost Distribution and Lengths of Various Pipe Materials

Material	Original study			Adjusted values		
	Size range (in.)	Scaled length* (ft.)	Percent of sewer cost	Composite size	Equivalent length (ft.)	Percent of sewer cost
Vitrified clay	8–36	21, 316. 98	30. 64	12–24 in.	10, 414. 37	32. 86
Concrete	8–96	18, 332. 05	56. 87	12–24 in.	24, 657. 70	60. 98
Cast iron	8–96	3, 085. 95	5. 75	49. 00 lb.	2, 156. 73	6. 16
Asbestos cement	8–36	3, 187. 00	6. 74	----------	----------	--------
Total	------	45, 921. 98	100. 00	----------	37, 228. 80	100. 00

*Data scaled down for the $1 million hypothetical sewer project, from the original 733 projects.

Example of Computation for "Pipe in Trench" Category

In accordance with the general specifications of the projects reviewed "cost of sewer in trench" includes: (*a*) excavation, (*b*) cost of pipe, (*c*) placing and joining of the pipe, and (*d*) backfilling of the trench. Sheeting and shoring, gravel foundation, cradle or incasement of pipe, and surface restoration are excluded.

The pipe involved in the base contract information represents a wide range of sizes and types of material. To convert the linear feet of pipe to a material cost base required the development of a weighted unit price for each type material. This unit price was developed on

the basis of the average unit cost of the original total pipe size, footage, and type of material. Table IV shows these unit prices for the various pipe materials, and the total material costs for the "Pipe in trench" category of the hypothetical sewer project.

Table IV.—Material Cost Data for Category 7 "Pipe in Trench" of a Hypothetical $1 Million Sewer Construction Project

Type of material	Feet of pipe	Unit price	Material price
Vitrified clay	21, 316. 98	$1. 709	$36, 431
Concrete	18, 332. 05	3. 688	67, 609
Cast iron	3, 085. 95	2. 215	6, 835
Asbestos cement	3, 187. 00	2. 5122	8, 006
Totals	45, 921. 98		118, 881

Because of the lack of historical price data, the material components for pipe in category 7 were then adjusted as previously discussed. The resulting material quantities and costs are given in appendix A.

Labor rates and costs were developed using certified payroll data to determine the types of trades involved, their relative weight and average costs. These data, supplemented by information from *Building Construction Cost Data* (*8*), *Building and Public Works Administration, Estimating and Costing* (*9*), and "Relative Cost of Material and Labor—Construction of Water and Sewage Systems" (*10*), provide the basis for the labor distribution.

For category 7, the labor involved for the 45,922 ft. of pipe was:

	Hours	*Rate*	*Total*
Common labor	22, 492	$2. 88	$64, 777
Equipment operators	13, 950	3. 845	53, 638
			118, 415

The equipment cost component is based on known unit costs per hour of use from the Kansas City area, hours of use per linear footage of sewers installed and combinations of sizes and types of equipment in use, supplemented or extended by using *Compilation of Rental Rates for Construction Equipment* (*11*), *Contractor's Equipment Ownership Expenses* (*12*), and *Construction Planning, Equipment and Methods* (*13*). This approach was necessitated by the wide variety of sizes of pipe installed and materials excavated. In order to arrive at the unit cost per hour for equipment, the unit costs per hour from Kansas City for a variety of sizes of backhoes, cranes, drag lines, compressors, bulldozers, etc., were combined to obtain a

weighted average unit cost. This was then extended by the equipment operator's time to obtain the category cost item.

Operating hours	*Cost/Hour*	*Total cost*
13,950	$10.7945	$150,583

Having established the cost items for materials, men, and machinery for the construction category, these were then subtracted from the total category cost to obtain the cost of the overhead and profit item.

Total category cost−(Material cost+Labor cost+Contractor's plant cost)=Overhead and profit cost.

For category 7, beginning with the total category cost from table II: $466,200−($118,881+$118,415+$150,583)=$78,321.

This procedure was applied to each of the construction categories and resulted in the cost values shown in table V.

Table V.—Component Costs for the Construction Categories of a Hypothetical $1 Million Sewer Construction Project

Construction categories	Material	Labor	Contractor's plant	Overhead and profit	Totals
1. Paving	$2,516	$1,620	$3,784	$880	$8,800
2. Sheeting and shoring	1,750	1,142	1,428	580	4,900
3. Manholes	12,420	7,410	6,200	7,470	33,500
4. Earth excavation	0	8,500	12,740	8,260	29,500
5. Rock excavation	2,100	4,480	6,720	5,000	18,300
6. Seeding and sodding	21	53	21	5	100
7. Pipe in trench	118,881	118,415	150,583	78,321	466,200
8. Lump sum items	217,512	43,180	131,524	46,484	438,700
Totals	355,200	184,800	313,000	147,000	1,000,000

Computation of Total Category Cost

Using the hypothetical sewer project category cost allocations, it then is convenient to express each component as a fixed percent of the total category cost. This makes it possible to use historically available published prices for material and labor to compute total category costs. These percentages are shown in table VI and are based on the data in table V for the $1 million hypothetical sewer construction project. With this percent allocation, it is possible to compute the complete project breakdown for any situation where material and labor information is available.

Table VI.—Percentage Breakdown of Components of the Various Construction Categories of a Hypothetical $1 Million Sewer Construction Project

Construction categories	Component as percent of category cost				Category cost percent of total plant cost
	Material	Labor	Contractor's plant	Overhead and profit	
1. Paving	28. 6	18. 4	43. 0	10. 0	0. 88
2. Sheeting and shoring	35. 7	23. 3	29. 2	11. 8	. 49
3. Manholes	37. 1	22. 1	18. 5	22. 3	3. 35
4. Earth excavation	0. 0	28. 8	43. 2	28. 0	2. 95
5. Rock excavation	11. 5	24. 5	36. 7	27. 3	1. 83
6. Seeding and sodding	21. 0	53. 0	21. 0	5. 0	. 01
7. Pipe in trench	25. 5	25. 4	32. 3	16. 8	46. 62
8. Lump sum items	49. 6	9. 8	30. 0	10. 6	43. 87
Total	35. 52	18. 48	31. 30	14. 70	100. 00

COMPUTATION OF NATIONAL INDEX

Calculating Total Prices

Unit prices for a given time period and location may now be multiplied by the total quantity factors given in appendix A to determine the total quantity costs for the material and labor for each category. The sum of these total quantity costs then represents the category cost in terms of material and labor. The combined material and labor costs then provide the basis to compute the contractor's plant cost, the overhead and profit cost, and thus the total category cost, using the cost relationships from table VI. This procedure was followed to calculate the value of each category over the entire period of the study. The sum of these total category costs for a given time period equals the total sewer project cost for that period.

Trade Area Cost Differences

Costs for materials and services vary markedly throughout the United States, with no apparent direct correlation, one to another. To reflect these cost variations, it is desirable to develop a number of indexes keyed to certain geographical areas of influence. In this way maximum use of the data can be made. Historically, 20 trade centers have been established and unit prices are reported regularly for them by *Engineering News-Record*. These 20 trade centers are:

Atlanta, Ga.
Baltimore, Md.
Birmingham, Ala.
Boston, Mass.
Chicago, Ill.
Cincinnati, Ohio
Cleveland, Ohio
Dallas, Tex.
Denver, Colo.
Detroit, Mich.

Kansas City, Mo.	Philadelphia, Pa.
Los Angeles, Calif.	Pittsburgh, Pa.
Minneapolis, Minn.	St. Louis, Mo.
New Orleans, La.	San Francisco, Calif.
New York, N.Y.	Seattle, Wash.

Appendix C shows these 20 trade centers and their assigned areas of influence. The national index is based on the sum of the cost of identical projects priced for each of these areas.

Establishment of Base Period Cost

The base period cost for the index was computed by averaging the total project cost for each of the 20 trade centers on a monthly basis for the 36-months of 1957 through 1959. This base value was then equated to 100.

To compute the National Sewer Construction Cost Index for any time period, the average of the project costs for the 20 trade centers for that period is divided by the base value (appendix D) and multiplied by 100.

For example, the national index for August 1962 was computed as follows:

$$\text{Average of 20 cities project cost for August 1962} = \$1{,}010{,}487$$
$$\text{Average of 20 cities project cost for base period} = \$920{,}969$$
$$\text{National index} = \frac{\$1{,}010{,}487}{\$920{,}969} \times 100 = 109.72$$

Computation of Individual City Index

The Sewer Construction Cost Index for each of the 20 trade areas mentioned was determined by substituting the individual city project cost for the average city project cost in the index formula. Thus, the ratio of a particular city project cost to the base period project cost yields the city index. For example, the computation for Kansas City in August 1962 is as follows:

$$\text{Kansas City project cost} = \$1{,}008{,}093$$
$$\text{Base period project cost} = \$920{,}969$$
$$\text{Kansas City index} = \frac{\$1{,}008{,}093}{\$920{,}969} \times 100 = 109.46$$

Price data for each of the 20 cities for the month of August for the years 1930 through 1963 were obtained from *Engineering News-Record* (*6*) and the *BLS Wholesale Prices and Price Indexes* (*14*). In the event these sources did not cover the entire historical period, interpolation was used based on similarity of materials or trades at commencement of the series. This was done principally for labor trades in the early 1930's. Electronic data processing was used to

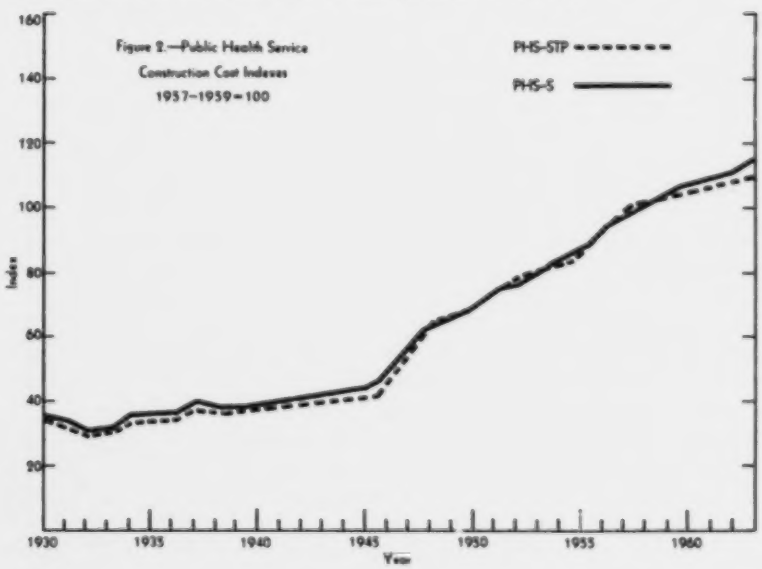
manipulate all data and calculate the individual city indexes and the national index for each year.

The indexes for each of the 20 cities, and the national index from 1930 through 1963 for the month of August are tabulated in appendix E and are shown graphically in appendix F. These indexes will be extended on a monthly basis from current price data published by *Engineering News-Record* (*6*) and BLS wholesale prices (14).

DISCUSSION

The PHS–S Construction Cost Index is presented graphically in two forms for comparative purposes. The first shows the index (fig. 2) in comparison with the PHS–STP (*7*) and is plotted on the base of 1957–59=100. The second (fig. 3) shows the PHS–S Index in comparison with the ENR Construction Cost Index (ENR–C) (*6*) and is converted to the base 1930=100. The converted PHS–S is tabulated in appendix E.

The PHS–S (fig. 2) increased slightly during the first 15 years of the study from its initial value of 35.90 in 1930 to 44.35 in 1945. The postwar years, 1946 to 1948, comprised the period of maximum increase, in which the index rose almost 20 points in the 3 years. Over the next decade (1949–59) the index rose at an almost constant annual rate of 3.75 percent. Since 1959, the index hes continued to rise, but at the reduced rate of 2.07 percent annually.



During the early years and until the late fifties, the PHS–S closely follows the PHS–STP (fig. 2). However, since 1959, the PHS–S has been increasing at a substantially greater rate (2.07 percent) than the PHS–STP, which is rising at an annual rate of 1.11 percent (7). This change in slope of the two indexes since 1959 is partially attributable to the continuing increase in pipe costs reflected in the PHS–S as compared to the static cost of concrete as reflected in the PHS–STP.

The difference between the PHS–S and the PHS–STP is best illustrated by a comparison of the percentage breakdown of their four major components of construction—material, labor, contractor's plant, and overhead and profit—as shown in table VII.

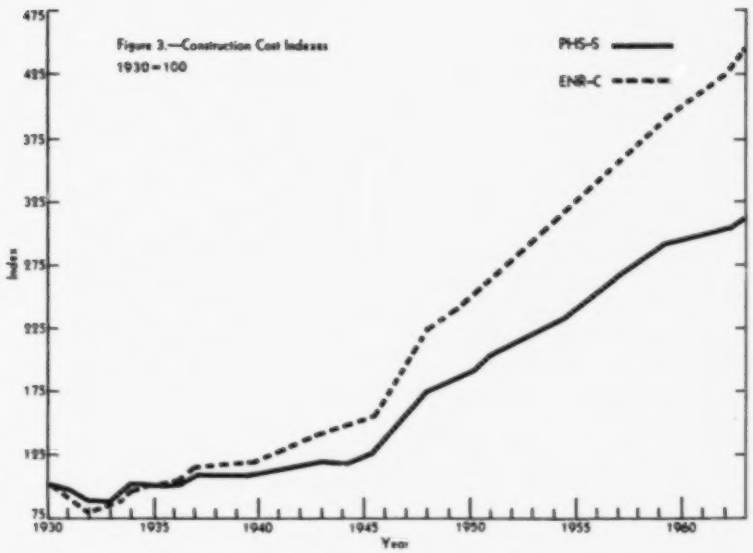
Table VII.—Major Components of Construction for Sewage Treatment Plants and Sewers

Items	Percent of total cost			
	Material	Labor	Contractor's plant	Overhead and profit
Sewage Treatment Plants (7)	54. 49	25. 33	6. 45	13. 73
Sewers	35. 52	18. 48	31. 30	14. 70

With the significant differences in material, labor, and contractor's plant shown in table VII, it is apparent that the two indexes can be influenced quite differently by changes in one or more of the many items that make up each.

Using the material component as an example, category 4, "Pipes, Valves, and Fittings" account for 10 percent of the material cost in the PHS–STP (7) as compared to 33 percent for the similar category (category 7) "Pipe in trench" in the PHS–S. Reducing these values by the percentages given in table VII shows that a shift in pipe costs will have over twice the effect on the PHS–S, as it will have on the PHS–STP. Similar variations are noted when comparisons are made for each item of material or labor that is involved in the two indexes.

Figure 3 shows that during the 1930's, the PHS–S and the ENR–C closely approximated each other. However, since the early 1940's the ENR–C has increased annually at a rate of one and a half times that of the PHS–S. Despite this varying rate, the two indexes closely approximate each other as to shift in slope and duration of trends until 1959. Since then, the ENR–C has increased at an annual rate of twice that of the PHS–S. This divergence between the two indexes has been caused primarily by the heavy reliance of the ENR–C on common labor prices which have risen about 5 percent per annum, while the PHS–S utilizes both skilled and common labor whose aggregate increase has been about 4 percent. Equating both indexes



to 100 for 1930, the ENR–C has increased to 450.74, while the PHS–S has risen to 314.90 during the 33-year period studied.

The PHS–S was developed using price data from a selected area of the United States and consequently is biased toward this area. It is felt that the bias is minimal due to the close approximation of the average national data to the selected data used in the development of the index. The utilization of fixed percents for contractor's plant, and overhead and profit is also a limiting factor in use of the index. This factor precludes the index from responding to changing money market conditions and technical advances. Neither of these limitations is unique to this index, and it is believed that even with these restrictions the PHS–S is the most responsive index for the sewer construction field because of its reliance on information peculiar to sewer construction.

This index may be used to adjust sewer construction costs from one part of the country to another, as well as from one time period to another. This will further enable the application of past and current cost experience directly to new or proposed work of a similar nature in the same or other geographic locations.

The PHS–STP and the PHS–S complement each other and provide a more accurate means of adjusting and comparing price in the sewerage field than would a single index. The inherent differences between sewer and plant construction preclude the use of a single index. Neither the PHS–STP nor the PHS–S is a valid substitute for the other.

To insure that the Sewer Construction Cost Index (PHS–S) continues to reflect current sewer construction practices and costs, reevaluation of the index base will be undertaken at regular intervals. If necessary, revisions or modifications of the index will be made.

CONCLUSIONS

1. A study of the various factors affecting the construction costs of sewers has led to the development of a Sewer Construction Cost Index.

2. The new Sewer Construction Cost Index more accurately reflects the special conditions inherent in sewer construction, and therefore, is of more direct use for this purpose than other published construction cost indexes.

3. The study shows that the construction costs of sewers have increased steadily during the last 30 years. Since 1959, the rate of increase has been slightly less than during the preceding 11 years.

4. This index may be used to evaluate past sewer construction activity and to estimate future sewer construction cost requirements for the 20 areas of influence in the United States and also for the Nation as a whole.

5. As an indicator of sewer construction cost trends—and as a public service—this index will be extended on a monthly basis. It will also be reexamined each decade or more often to account for changes in fundamental assumptions.

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Appendices

APPENDIX A

Material and Labor Cost Analysis of the Construction at Kansas City,

Category	Material			
	Components	Quantity	Unit cost	Item cost
1. Paving	Concrete (cu. yd.)	115.92	$13.50	$1,564.92
	Earth (cu. yd.)	278.08	1.90	528.35
	Rock (cu. yd.)	201.25	2.10	422.63
				2,516.00
2. Sheeting and shoring	Lumber (1,000 sq. ft.)	7.51	200.00	1,540.00
	Structural steel (100 lbs.)	9.46	10.34	67.50
	Structural shapes (100 lbs.)	19.96	6.17	122.50
				1,750.00
3. Manholes	Concrete (cu. yd.)	243.90	13.50	3,291.30
	Reinforced steel (100 lbs.)	297.30	7.10	2,111.40
	Flyform (1,000 sq. ft.)	6.24	200.00	1,279.20
	Cast iron (tons)	9.32	138.60	1,291.68
	Bricks (1,000)	73.79	30.00	2,955.90
	Concrete blocks (each)	6,774.55	.22	1,490.40
				12,420.00
4. Earth excavation				
5. Rock excavation	Gravel (cu. yd.)	1,000.00	2.10	2,100.00
				2,100.00
6. Seeding and sodding	Top soil (cu. yd.)	5.63	3.60	21.00
				21.00
7. Pipe in trench	Cast iron (tons)	52.94	138.60	7,333.07
	Vitrified clay pipe (lin. ft.)	10,414.27	7.751	39,984.20
	Concrete pipe (lin. ft.)	24,657.70	2.94	72,443.63
				119,960.90
9. Lump sum (other items)	Concrete (cu. yd.)	2,271.79	13.50	30,689.19
	Reinforced steel (100 lbs.)	2,792.63	7.10	19,703.50
	Flyform (1,000 sq. ft.)	56.36	200.00	11,965.16
	Structural shapes (100 lbs.)	11,674.97	10.34	120,719.16
	Cast iron (tons)	216.57	138.60	30,016.66
	Structural steel shapes (100 lbs.)	367.97	6.167	3,392.63
	Pig iron (tons)	29.44	60.50	1,657.61
				217,512.69
Total project				355,260.00

Categories for a $1 Million Hypothetical Sewer Project Mo., Aug. 1, 1962

Labor[1]				Category cost
Class/Trade	Man-hours	Unit cost	Item cost	
Equipment operators	200.14	$0.040	$5,347.60	
Carpenters	41.91	3.977	102.00	
Common labor	28.15	2.99	110.17	
			1,035.00	$4,130.00
Carpenters	140.07	3.075	710.00	
Ironworkers	69.00	4.125	344.30	
Common labor	61.00	2.00	178.24	
			1,142.00	2,682.00
Equipment operators	337.07	3.943	1,981.00	
Carpenters	24.30	3.975	96.47	
Ironworkers	53.45	4.010	210.11	
Bricklayers	1,150.07	4.210	5,000.00	
Common labor	40.70	2.00	140.42	
			7,410.00	10,680.40
Equipment operators	1,100.20	3.940	4,337.54	
Common labor	1,373.71	2.00	3,902.00	
			8,300.00	8,000.00
Equipment operators	822.10	3.940	2,360.40	
Common labor	734.42	2.00	2,000.27	
			4,400.00	6,000.00
Equipment operators	5.50	3.940	20.42	
Common labor	10.00	2.00	30.00	
			50.00	74.00
Equipment operators	13,000.00	3.940	52,020.00	
Common labor	22,402.00	2.00	64,777.00	
			116,410.00	187,290.00
Equipment operators	2,194.20	3.940	8,200.44	
Carpenters	4,322.33	3.875	17,324.00	
Ironworkers	200.00	4.010	802.01	
Electricians	80.00	4.50	400.00	
Common labor	5,104.21	2.00	10,020.02	
			45,190.00	200,000.00
			186,000.00	640,000.00

APPENDIX B

Sewer Pipe Cost Relationships

Part 1

An analysis of the cost per diameter inch per foot of pipe over a period of years disclosed that there was a constant differential between pipes of varying diameter Using this constant differential, the statistical method of "least squares" was used to determine the best fitting linear curve. The straight line appearing in figure I had the form of $y=a+bx$ in which y is the cost and x is the diameter of the pipe, based upon the following data:

Reinforced Concrete Sewer Pipe—Kansas City, Mo., Aug. 1, 1962

Diameter of pipe in ft.	Cost/ft. of length	Cost/diameter in/ft. of length
0.67	$0.296	$0.037
1.00	.744	.062
1.50	1.188	.066
2.00	1.752	.073
2.25	2.214	.082
2.50	2.580	.086
3.00	3.492	.097
3.50	4.536	.108
4.00	5.712	.119
4.50	6.966	.129
5.00	8.460	.141
5.50	9.966	.151
6.00	11.952	.166
7.00	14.784	.176
8.00	19.488	.203

The resultant equation for reinforced concrete pipe is $y = .032066 + .021368x$.

Part 2

Example: Estimating Pipe Cost

Using the cost of a known diameter of pipe, the estimated cost of a second size pipe is determined by solving the following equation:

$$y_2 = y_1 + b(x_1 - x_2)$$

in which y_2 = unknown pipe cost
y_1 = cost of pipe known
$b = .021368$
$x_1 - x_2$ = difference in diameter between pipes in feet.

To estimate the cost of 60-inch pipe with the cost of 24-inch pipe known the following calculations result. Using the cost for 24-inch pipe given in the tabulation of $0.073 per diameter-inch:

$y_2 = .073 + .021368(5-2)$
$y_2 = .073 + .064104$
$y_2 = .137$ (which is $\pm$ 3 percent of the actual value)

APPENDIX C

The 20 Index Cities and Their Assigned Areas of Influence

APPENDIX D

Total Sewer Project
[Base Period

Cities	Paving	Sheeting and shoring	Manholes
1. Atlanta	$7, 325. 96	$4, 079. 23	$27, 888. 61
2. Baltimore	7, 647. 42	4, 258. 22	29, 112. 35
3. Birmingham	6, 739. 46	3, 752. 65	25, 655. 88
4. Boston	8, 583. 99	4, 779. 72	32, 677. 68
5. Chicago	8, 771. 42	4, 884. 09	33, 391. 21
6. Cincinnati	7, 795. 24	4, 340. 53	29, 675. 04
7. Cleveland	8, 336. 29	4, 641. 80	31, 734. 72
8. Dallas	7, 020. 81	3, 909. 31	26, 726. 94
9. Denver	7, 172. 90	3, 994. 00	27, 305. 91
10. Detroit	8, 759. 58	4, 877. 50	33, 346. 15
11. Kansas City	7, 762. 79	4, 322. 46	29, 551. 52
12. Los Angeles	8, 272. 57	4, 606. 32	31, 492. 18
13. Minneapolis	8, 993. 24	5, 007. 60	34, 235. 62
14. New Orleans	7, 215. 81	4, 017. 89	27, 469. 26
15. New York	9, 620. 53	5, 356. 89	36, 623. 62
16. Philadelphia	8, 429. 68	4, 693. 80	32, 090. 26
17. Pittsburgh	8, 279. 82	4, 610. 35	31, 519. 76
18. St. Louis	7, 989. 27	4, 448. 57	30, 413. 71
19. San Francisco	8, 510. 80	4, 738. 97	32, 399. 07
20. Seattle	8, 863. 00	4, 935. 08	33, 739. 81

Costs for 20 Index Cities
=1957–59]

Earth excavation	Rock excavation	Seeding and sodding	Pipe in trench	Lump sum items	Total plant cost
$24, 558. 63	$15, 234. 67	$83. 25	$388, 109. 57	$365, 215. 94	$832, 495. 86
25, 636. 25	15, 903. 17	86. 90	405, 139. 70	381, 241. 52	869, 025. 53
22, 592. 49	14, 015. 00	76. 58	357. 037. 99	335. 977. 20	765. 847. 25
28, 775. 87	17, 850. 79	97. 55	454, 756. 23	427, 931. 25	975, 453. 08
29, 404. 20	18, 240. 60	99. 68	464, 685. 99	437, 275. 25	996, 752. 44
26, 131. 76	16, 210. 55	88. 58	412, 970. 32	388, 610. 20	885, 822. 22
27, 945. 50	17, 335. 68	94. 73	441, 633. 68	415, 582. 79	947, 305. 19
23, 535. 66	14, 600. 09	79. 78	371, 943. 26	350, 003. 23	797, 819. 08
24, 045. 51	14, 916. 36	81. 51	380, 000. 51	357, 585. 21	815, 101. 91
29, 364. 52	18, 215. 95	99. 54	464, 058. 91	436, 685. 21	995, 407. 36
26, 022. 98	16, 143. 07	88. 21	411, 251. 26	386, 992. 54	882, 134. 83
27, 731. 92	17, 203. 19	94. 01	438, 258. 31	412, 406. 52	940, 065. 02
30, 147. 79	18, 701. 85	102. 20	476, 437. 21	448, 333. 32	1, 021, 958. 83
24, 189. 35	15, 005. 60	82. 00	382, 273. 69	359, 724. 28	819, 977. 88
32, 250. 65	20, 006. 34	109. 32	509, 669. 69	479, 605. 54	1, 093, 242. 58
28, 258. 59	17, 529. 90	95. 79	446, 581. 49	420, 238. 74	957, 918. 25
27, 756. 20	17, 218. 25	94. 09	438, 642. 10	412, 767. 68	940, 888. 25
26, 782. 22	16, 614. 06	90. 79	423, 249. 86	398, 283. 38	907, 871. 86
28, 530. 53	17, 698. 60	96. 72	450, 879. 02	424, 282. 76	967, 136. 47
29. 711. 18	18, 431. 00	100. 72	469, 537. 35	441, 840. 49	1, 007, 158. 63

APPENDIX E

Sewer Construction Cost

[1957–59

Years	Atlanta 1	Baltimore 2	Birmingham 3	Boston 4	Chicago 5	Cincinnati 6	Cleveland 7	Dallas 8	Denver 9	Detroit 10	Kansas City 11
1930	28.48	32.73	34.87	38.41	40.97	36.43	41.62	39.16	38.08	36.45	33.41
1931	27.72	32.14	25.69	36.42	37.97	33.53	39.96	33.86	35.36	35.82	36.54
1932	27.93	31.49	26.47	35.80	34.07	31.74	31.21	30.41	31.90	29.95	33.37
1933	27.79	31.86	27.69	34.93	36.48	29.13	34.23	34.81	31.87	28.45	32.66
1934	33.57	36.77	28.14	35.86	39.86	33.53	38.48	34.03	36.60	34.29	36.43
1935	32.45	37.20	29.01	36.69	39.91	33.52	38.39	30.24	36.60	33.06	36.93
1936	33.73	36.08	29.42	37.71	38.00	33.22	36.72	34.74	38.44	32.97	37.26
1937	38.00	38.51	30.85	40.80	37.32	39.50	40.25	35.11	42.83	37.55	38.76
1938	34.58	39.03	29.69	42.15	38.76	37.21	37.63	35.22	42.41	34.78	39.37
1939	32.91	38.19	29.74	41.01	39.45	37.72	38.48	35.01	42.64	34.33	39.42
1940	33.67	39.15	30.58	41.11	39.34	39.48	38.18	36.43	43.03	37.59	39.30
1941	34.14	42.22	30.95	40.96	39.48	39.13	39.89	40.71	43.15	39.14	39.58
1942	34.26	42.14	34.63	39.67	39.10	39.87	38.44	41.43	43.16	40.28	40.40
1943	35.11	45.15	34.81	44.61	43.07	40.44	39.32	42.89	45.50	41.12	42.45
1944	35.15	43.58	34.81	45.70	43.07	41.02	41.29	43.06	46.10	43.90	43.98
1945	38.51	44.59	35.39	45.03	44.30	41.59	43.85	44.37	46.32	45.58	43.54
1946	48.30	49.42	39.33	50.68	48.86	48.93	48.68	49.53	49.91	50.02	47.16
1947	53.42	53.32	48.90	58.28	61.42	56.48	56.96	55.05	58.47	58.42	51.99
1948	56.75	59.90	53.52	69.88	66.20	63.35	62.09	58.62	63.83	65.47	59.88
1949	56.51	65.66	55.78	73.23	70.17	62.69	66.89	60.00	64.22	67.54	62.73
1950	60.30	68.20	57.61	70.19	70.46	67.19	71.30	61.41	67.01	75.21	65.56
1951	64.32	72.80	62.40	81.65	78.27	73.47	75.44	69.18	71.19	80.32	69.98
1952	69.02	74.39	65.20	83.63	81.92	75.38	80.55	69.39	71.73	82.07	73.73
1953	76.82	79.18	67.97	86.66	85.63	80.08	84.46	71.21	75.67	89.07	76.84
1954	77.82	79.86	68.86	90.31	87.66	82.40	86.79	73.40	76.73	92.18	81.43
1955	80.25	82.02	72.80	93.23	91.66	85.64	92.98	74.32	79.88	96.99	85.88
1956	88.98	85.28	80.07	101.24	102.01	90.94	96.48	78.60	82.81	102.53	88.99
1957	90.70	91.60	79.99	105.17	107.07	94.40	101.05	83.81	85.65	105.24	91.48
1958	93.51	96.13	82.12	106.60	108.35	97.18	102.15	86.24	87.23	108.69	96.02
1959	92.57	98.41	86.30	103.25	112.15	97.79	106.58	91.28	94.14	112.40	100.58
1960	92.01	94.05	90.37	109.02	109.72	97.90	114.50	90.39	97.09	116.94	105.14
1961	91.89	95.50	90.67	110.60	111.56	101.35	113.47	90.05	94.13	118.18	107.71
1962	93.58	96.75	89.23	111.03	112.38	103.85	114.97	91.57	98.55	119.22	109.46
1963	98.71	110.58	92.65	117.07	114.98	103.51	111.98	93.98	99.01	121.11	110.96

Indexes, 1930–63, August Values

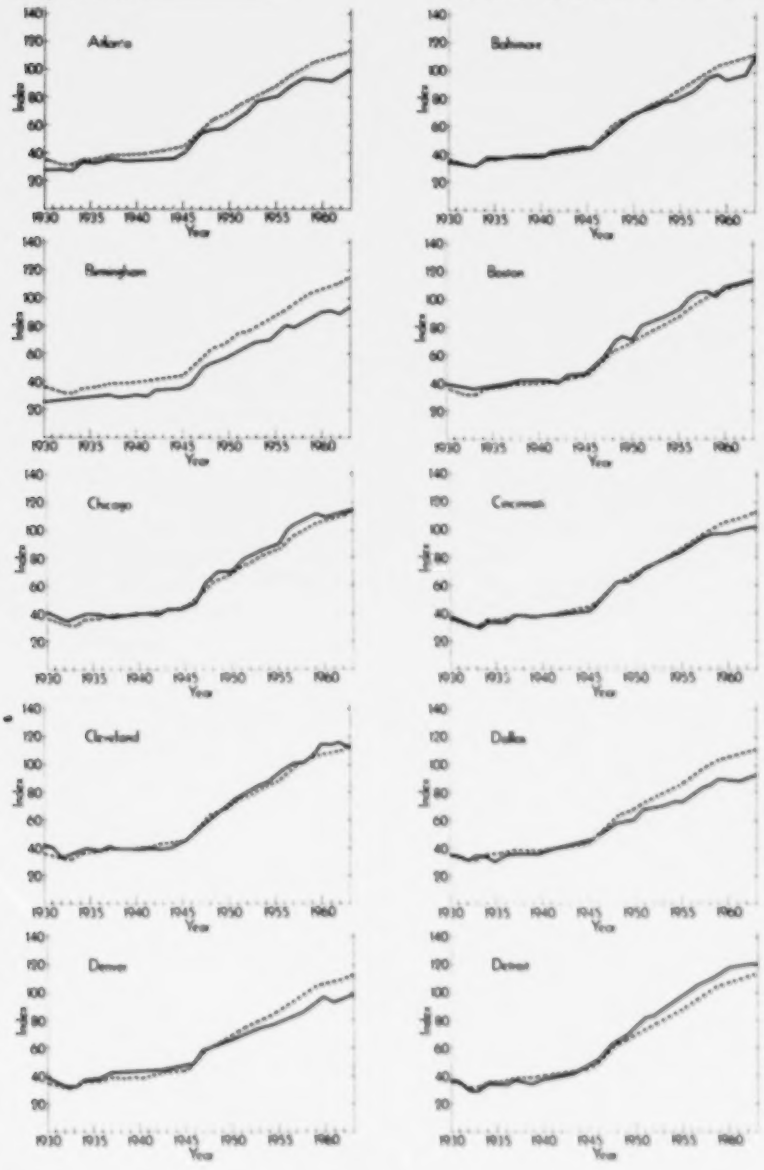
=100]

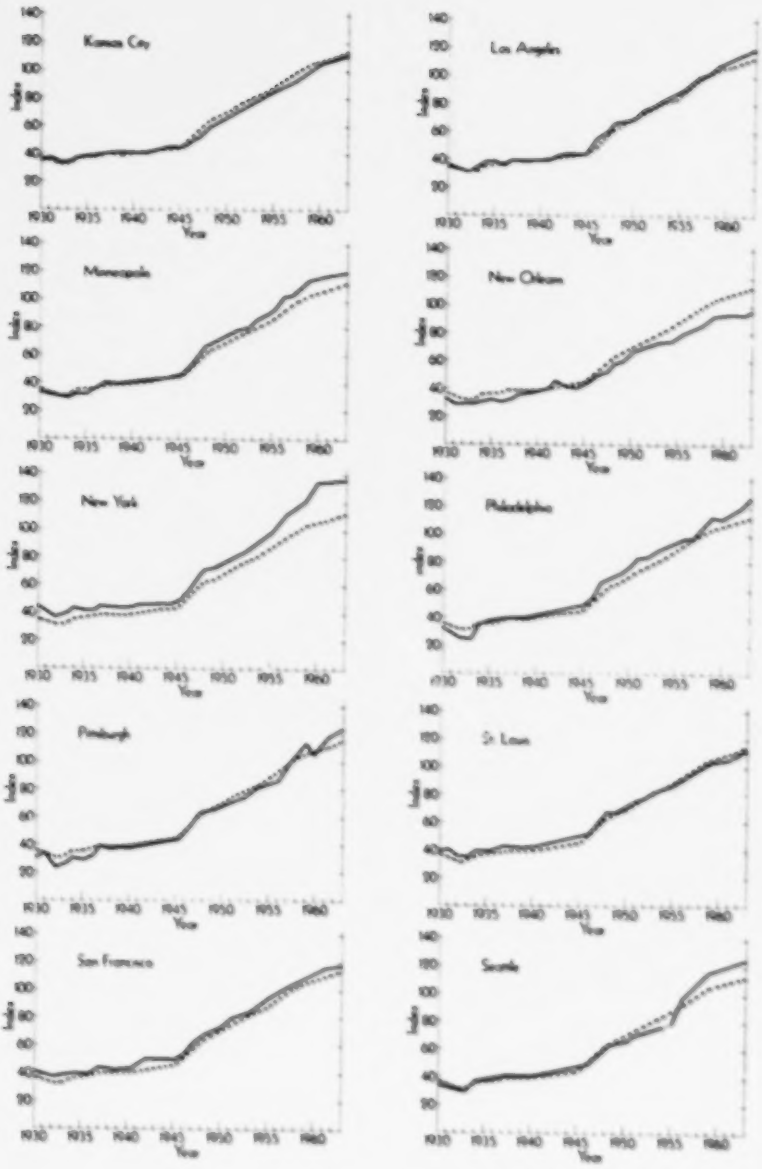
Los Angeles 12	Minneapolis 13	New Orleans 14	New York 15	Philadelphia 16	Pittsburgh 17	St. Louis 18	San Francisco 19	Seattle 20	National averages (1957–59=100)	National index (1930=100)	Years
34.10	33.28	32.52	43.87	31.07	31.38	38.41	39.67	33.15	35.90	100.00	1930
32.97	31.88	28.74	39.87	27.49	34.53	39.64	38.63	31.49	34.01	94.72	1931
30.64	30.64	28.31	36.43	23.60	24.41	34.19	35.31	29.56	30.87	85.97	1932
33.49	29.98	29.19	38.54	23.98	25.06	33.93	35.95	29.12	31.46	87.62	1933
37.68	32.76	30.41	42.89	34.59	30.58	39.75	37.75	36.89	35.54	98.96	1934
38.03	31.82	31.93	40.55	36.94	29.54	38.07	37.80	38.70	35.35	98.45	1935
35.90	36.38	30.58	41.06	37.35	32.27	38.45	37.65	39.35	35.88	99.93	1936
39.93	40.47	32.41	45.06	39.67	38.33	42.18	42.67	40.80	38.95	108.46	1937
39.92	39.95	35.92	43.89	39.12	37.13	41.27	42.19	39.74	38.50	107.22	1938
39.01	40.14	35.51	43.04	38.21	38.39	41.23	41.83	39.67	38.30	106.67	1939
39.21	40.37	39.21	43.31	41.29	37.73	41.06	42.30	39.61	39.10	108.89	1940
39.62	41.03	39.34	45.42	41.97	38.43	42.88	45.41	40.07	40.18	111.90	1941
42.84	43.26	45.48	45.66	43.37	40.61	44.47	48.97	42.98	41.55	115.72	1942
43.13	43.20	41.61	45.02	44.48	41.58	46.59	47.81	44.96	42.54	118.47	1943
43.13	43.76	41.32	45.39	46.32	42.69	47.50	48.14	45.08	43.28	117.75	1944
44.83	45.00	43.12	47.53	47.82	43.51	47.74	48.23	46.05	44.35	123.51	1945
55.17	50.40	48.64	53.66	53.31	49.21	51.13	52.30	48.23	49.64	138.25	1946
59.56	60.50	51.12	64.60	64.51	58.33	59.39	60.98	54.96	57.33	159.66	1947
65.63	68.66	56.51	72.43	67.79	62.00	66.98	66.61	63.00	63.60	177.13	1948
67.00	70.13	59.59	72.92	71.08	63.99	66.96	69.96	64.32	65.57	182.61	1949
68.83	73.36	65.48	77.36	75.07	68.03	69.45	72.18	65.74	68.51	190.80	1950
75.16	79.33	69.13	80.87	82.94	70.66	74.56	79.09	70.12	74.04	206.20	1951
77.56	80.05	71.01	84.38	82.57	73.08	76.40	82.35	72.24	76.33	212.58	1952
83.69	86.65	73.94	89.76	88.70	78.68	80.59	82.90	73.83	80.62	224.53	1953
86.73	89.26	74.46	93.79	90.51	81.79	83.59	88.40	76.52	83.12	231.49	1954
89.91	93.51	77.56	96.59	94.49	84.60	86.87	94.06	78.90	86.71	241.49	1955
94.01	103.84	81.39	108.93	96.98	85.49	90.89	97.29	95.44	92.48	257.58	1956
100.42	104.87	84.79	114.40	98.10	97.25	95.09	102.86	102.43	96.80	269.59	1957
101.96	111.28	88.07	119.81	106.25	101.58	98.28	105.29	111.89	100.43	279.67	1958
108.37	116.97	93.72	123.74	112.81	114.26	104.44	108.62	116.98	104.73	291.81	1959
110.86	117.83	93.24	135.25	111.93	104.48	104.40	112.18	117.18	106.22	295.82	1960
114.95	119.58	94.78	137.64	115.82	114.08	106.09	115.30	120.85	108.19	301.31	1961
117.38	120.04	93.63	137.68	119.63	120.41	108.50	116.00	122.55	109.72	305.57	1962
118.99	120.49	96.47	138.58	126.30	122.88	110.88	127.37	125.14	113.07	314.90	1963

APPENDIX F

Individual City Indexes and National Index 1930–63

City Index ———— **National Index** - - - - - -




Kansas City
Los Angeles
Minneapolis
New Orleans
New York
Philadelphia
Pittsburgh
St. Louis
San Francisco
Seattle
Index
Year
1930 1935 1940 1945 1950 1955 1960